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ABSTRACT

This discussion of radiation considers the spectrum of electromagnetic energy including light, x-rays, radioactivity, and other waves. Radiation is considered from three aspects; time, space, and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters on the history and concepts of radiation, a time line related to the concepts, a map of the important geography of these concepts, a glossary of important terms, and a list of several study suggestions are included. (CW)

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Radiation

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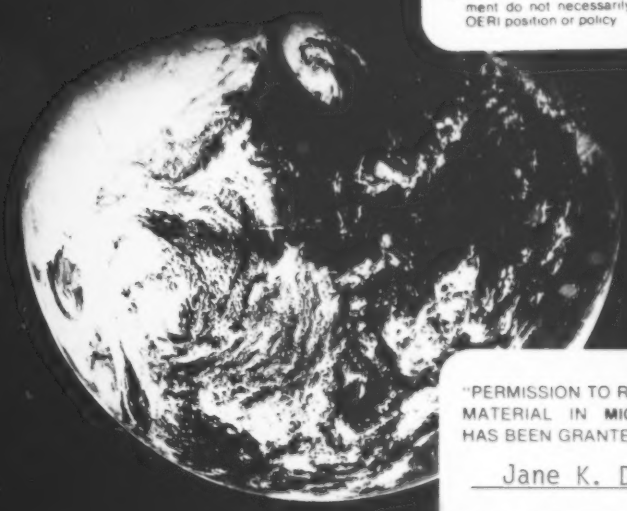

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A HAWKHILL LEARNING POWER BOOK

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SE 051 129

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more–much more–in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this–the way this book follows–is to look at the world from three angles: *Time, Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles–*Time, Space* and *Spirit*.

Read on.

This book belongs to:

Radiation

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit--Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit--Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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Part 1: How Radiation Was Discovered

a romantic story

A story is told of a young physicist, Fritz Houtermans. One summer evening he was feeling exhilarated as he strolled down a quiet street in the old university town of Gottingen, Germany. His girlfriend was at his side. She sensed his mood, looked up at the night sky and said softly, "Look up at the stars. Aren't they beautiful."

"Yes," replied the young physicist, "and do you know you are holding hands with the only man alive who knows why they shine?"

how the sun works

He was telling the literal truth. That very day Houtermans had discovered just what the nuclear reactions were that gave the stars (and our own sun) their shining radiant energy.

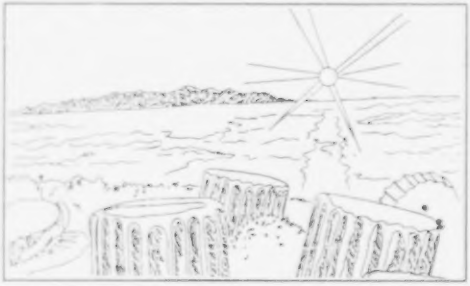
two sides to the story

It is good to start a lesson on radiation with this story because many people think of radiation today mostly in terms of its dangers. Like everything else in science and society, there are at least two sides to the story, and we have a lot to learn

about both. Though radiation is as old as the universe itself, penetrating the mysteries of radiation has only just begun.

gifts of sunlight

The first kind of radiation to be studied was light–visible light. From ancient times people have been fascinated by light. And with good reason. Some people worshipped the sun, the source of this radiant gift. Farmers knew that light was needed to grow crops. Sailors knew that light brought changes in the weather. And everyone knew that light brought warmth, sight and beauty.



what is light?

But no one knew what light was. How it was made. How it moved. What happened to it when it disappeared.

early theories

At the dawn of science in ancient Greece, scientists like Anaximander, Aristotle and Democritus wondered about light and made up theories to explain it. Democritus, for example, said light was made of tiny little bullets streaming away from sources like the sun. These little bullets would bounce off whatever they hit, warming it in the process. Euclid even formulated some laws to describe how light reflected from mirrored surfaces and bent as it went through water and glass.

Newton breaks light into colors

One of the first scientists to solve some of the mysteries of color–almost two thousand years after Democritus and Euclid–was Isaac Newton. Working alone at his country home in Woolsthorpe, England, where he retired to escape the

plague in 1665, Newton used a prism to break up sunlight into colors.

white light a combination

The colored rays, he found, could not be further separated. They could be put back together, however, to make white light again. Thus, said Newton, contrary to what was commonly believed at the time, it is white light that is the mixture. Each of the colors is its own pure ray.

light a stream of particles

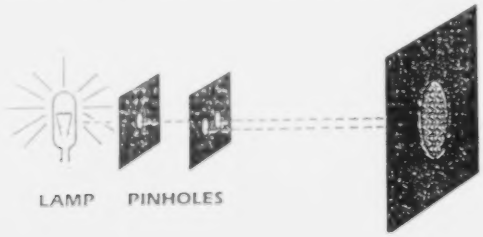
Newton, like Democritus, said that each colored ray must be a stream of tiny particles since light always cast sharp shadows and did not bend to go around corners the way a wave would.

or is it?

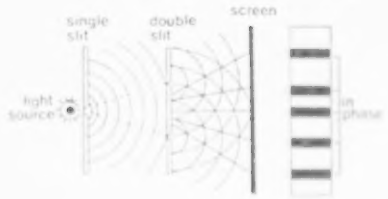
It took over a hundred years to prove Newton wrong on this last point. It was on November 24, 1803 that another English scientist, Thomas Young, performed a simple, elegant experiment in front of the Royal Society in London. Light was not a particle, but a wave, said Young. And here is the proof.

Young's experiment

He shone a thin beam of light through two small holes. He pointed triumphantly to the telltale bands of light and dark streaks that appeared on



the screen behind the holes. Just look, said Young, if you split a beam of light you do get bending!



Just like a wave, light produces patterns of light and dark bands as the light waves cancel and add to one another. If light was a simple stream of tiny particles, these bands of dark and light could not happen.

light is a wave

Young later figured out in his experiments the actual wavelengths of light, which turned out to be very small indeed–smaller than a millionth of a meter.

or is it?

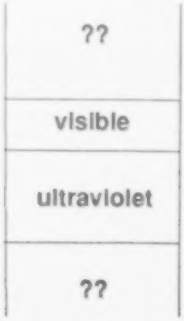
This did not end the controversy over light being a wave or a particle, however. In fact, it has continued right down to our own day. And the scientific view today is that light is both a wave and a particle!

a spectrum of light

Let's look at how Newton's and Young's work opened the door to the widening spectrum of radiation. They studied the visible spectrum from red to yellow to blue and violet. Soon other scientists were finding there was invisible *light*. That is, radiation that fanned out on either side of this visible spectrum in a much broader rainbow of color.

ultraviolet light

There was not only violet light, there was an *ultraviolet* light. Ultraviolet light could not be seen with the eye, but when it shone on certain minerals, it made these minerals glow with what came to be called a *black light*.



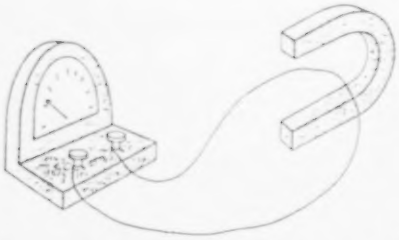
infrared light

And off the other end of the spectrum, after red light, there was found to be an *infrared* light that one could not see, but one could feel as warmth. More progress was made in the middle of the nineteenth century, expanding the spectrum of radiation.

what is electricity?

Pioneers like the Englishman Michael Faraday, the Dane Hans Christian Oersted, the Italian Alessandro Volta and the American Joseph Henry made slow progress in discovering new facts and laws about electricity and magnetism.

Electricity moving through a wire, it was found, would affect a magnetic needle. And vice versa! A moving magnet would make electricity flow through a wire. The basic principles were there for later construction of electric motors and generators. And more important for our subject, new questions arose.



investigating the electrical field

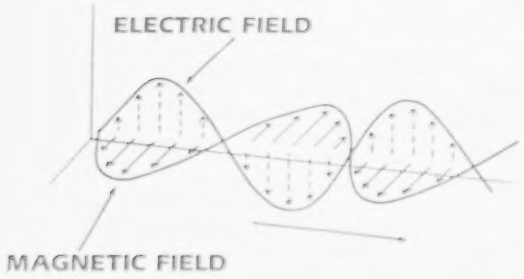
What was the *field* surrounding magnets and electrical conductors? Something seemed to *radiate* out from these strange magnets and electrical devices? Did it have anything to do with the radiation we already knew something about?

Maxwell finds new waves

In the middle of the nineteenth century, the Scottish physicist and mathematician James Clerk Maxwell found some answers to these questions.

electromagnetic waves

Surrounding any current carrying wire, said Maxwell, is a moving-out field of electromagnetic waves. And–amazing fact–these electromagnetic waves act very much like visible light waves.



Like visible light waves, electromagnetic waves reflect, refract and are absorbed. And–here was the clincher–they move at the same speed and follow the same mathematical laws as light.

the spectrum widens

Suddenly the spectrum of radiation was multiplied manyfold. Not only do we have red, yellow and blue light; not only do we have ultraviolet and infrared light; now we have a whole new world of radiating electromagnetic waves. All with longer wavelengths and lower frequencies than visible light. Later these longer wavelengths, lower-frequency waves of radiation came to be known as the familiar radio, television, radar and microwave frequencies.

radio & television
microwave & radar
infrared
visible light
ultraviolet
???

How about the other end of the spectrum? Could there be electromagnetic waves with shorter wavelengths and higher frequencies than ultravio-

Yes, indeed. Though it took another fifty years to discover any such waves.

x rays are discovered

The first ones to be discovered were the electromagnetic waves just above ultraviolet on our spectrum. X rays.

The discovery of x rays by the German physicist Wilhelm Roentgen in 1895 was an international sensation. Working with vacuum tubes, he bombarded a metal plate with high-speed electrons. He found that invisible rays were produced. These mysterious new rays could go through skin and flesh and give a picture of a person's bones.

a worldwide sensation

His x rays became world famous–as well as world misunderstood. A legislator in New Jersey introduced a bill banning their use in opera glasses in order to preserve the modesty of ladies.

many uses for x rays

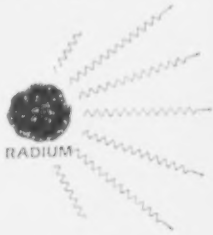
X rays soon found many valuable uses in medicine and in industry. It was, unfortunately, quite a few years later that a harmful side of x rays was also discovered. They could be harmful to living tissue, or even cause cancer if the exposures were too great or too prolonged.

radioactivity is discovered

So, too, with the next discovery in our radiation story– radioactivity. Here the first breakthroughs were also made around the turn of the century. Shortly after Roentgen discovered x rays, a Frenchman, Henri Becquerel, stumbled upon another kind of radiation. He found that the element uranium spontaneously gave off rays that would darken photographic plates, as did x rays.

Marie Curie in Paris

Marie Curie and her husband, Pierre, worked long hours in a drafty garage laboratory in Paris to isolate a new element, radium, that gave off very powerful new rays. What were these new rays? New forms of radiation? Experiments were done all over the world. Scientists found that some of the rays coming out of radium and uranium acted like electromagnetic waves. They were weightless. They traveled at the speed of light. And they obeyed all of the mathematical equations Maxwell had discovered for the electromagnetic spectrum. These were later called gamma rays. And indeed they were a part of the electromagnetic spectrum, with still shorter wavelengths and higher frequencies than x rays.



rays not on the spectrum

Besides the gamma rays, there were at least three other kinds of penetrating particles that came out of the radioactive atoms of radium and uranium. Each of the three kinds of rays acted quite differently from the others. And none of these three new kinds of radiation was a part of the electromagnetic spectrum.

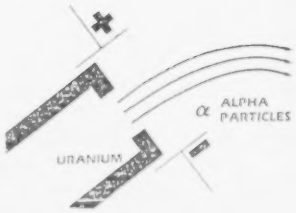
What were they then?

alpha rays

Well, one kind of ray turned out to be made of heavy particles that were easily stopped by a piece of paper or by the skin. A stream of them could be bent by a magnetic or electrical field.

positive changes

They were charged positively. They were named alpha particles. These alpha particles were later found to be identical to the nuclei of the element helium.

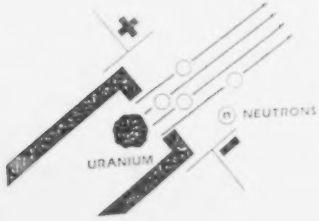


beta rays

Another kind of radiation coming out of radioactive elements was also made of particles. But these particles were much lighter, moved much faster, were more penetrating and were bent in the opposite direction than alpha particles by magnetic or electrical fields. These rays were named beta rays. Beta particles were found later to be identical to electrons.

neutron radiation

And finally, in certain rare cases, another kind of radiation came out of elements like uranium . These were particles, too, but they were not affected at all by magnetic or electrical fields. They were named neutrons. Neutrons were emitted when a uranium nucleus fissioned. That is, when it split in two or more parts, and in the splitting emitted very large amounts of energy as well.



where rays come from

In the twentieth century, physicists discovered where electromagnetic waves come from. All of them, except the gamma rays, come from leaps of electrons inside of atoms, or from the vibrations of atoms and molecules.

new world of electronics

Engineers soon learned to control these electron leaps, these atomic vibrations. The result was radio, television, microwave ovens, computer circuits and the whole new world of electronic marvels.

nuclear energy

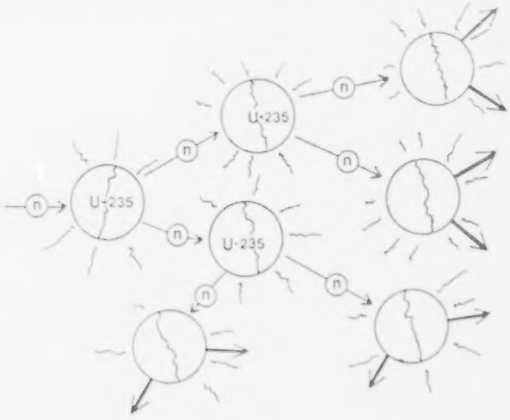
It was a somewhat different story with the other basic kind of radiation. The kind that comes out of radioactive elements like radium and uranium. The kind that is associated nowadays with nuclear energy.

energy from the center of the atom

Here the radiation came not from the leaping electrons of the outer atom, but rather from the cracking apart of the nucleus of certain atoms. In the case of naturally radioactive elements like radium and uranium, their nuclei are continually and randomly breaking apart. From this breaking apart we get alpha, beta and gamma rays, exploding out at high speeds and dangerous momentums.

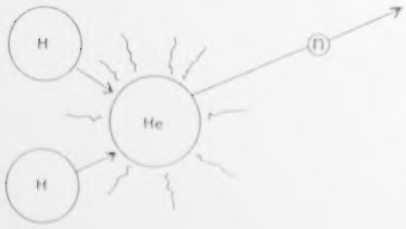
fission

When special kinds of uranium atoms' nuclei actually split in two, still another kind of radiation is emitted, high speed neutrons. This happens in a controlled way in a nuclear power plant, and in an uncontrolled way in a nuclear bomb. This atom splitting process is called nuclear fission.



fusion

And finally, when certain kinds of very light hydrogen atoms combine, that is, when their nuclei combine we also get radiation. In this case, we get the kind of radiation that Fritz Houtermans had figured out on that summer evening in Gottingen. The kind of radiation that our sun and our stars emit. The kind of atom combining process that is called nuclear fusion.

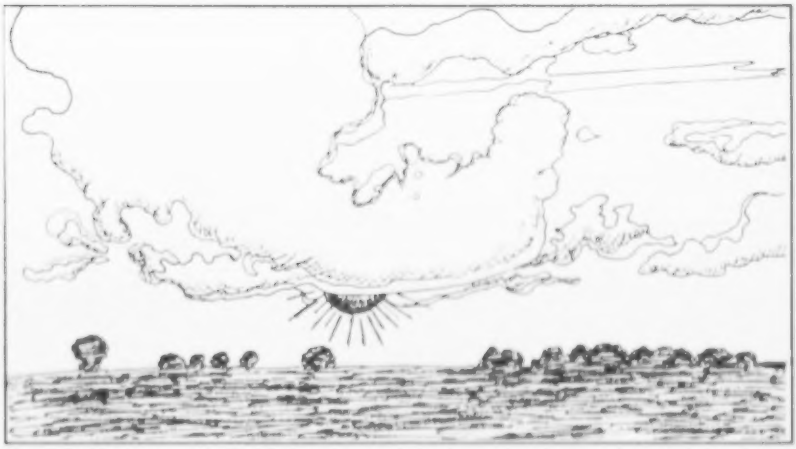


how radiation affects you

How all of these kinds of radiation affect living creatures like us is the subject of the second apart of this program, *Radiation and You*.

Read on.

Part 2: Radiation and You



atoms and radiation

The world is made of atoms. The world is powered by radiation. And the world includes you and me. In other words, we too are made of atoms and powered by radiation.

helpful and harmful

Like some kinds of atoms, some kinds of radiation can be harmful to living things. Like most atoms, most radiation is not only helpful, it is absolutely essential to life on this earth.

Like light, for instance. Visible light.

the power for all life

Light rays have been streaming in to earth from our brother sun for over five billion years. Those light rays from our sun have been the power behind all life on earth throughout these billions of years, and are the power behind all life on earth today.

speed of light

Like other kinds of radiation, light is itself weightless and invisible. Like other kinds of radiation light travels at 186,000 miles per second. Though

the sun is over ninety-three million miles away from earth, it takes only about eight seconds for light rays to get from the sun to us.

invisible in itself

Like other kinds of radiation, light, even though invisible in itself, can be detected by its effects on other things. Green leaves, blue sky, photographic paper, our eyes, to mention just a few.

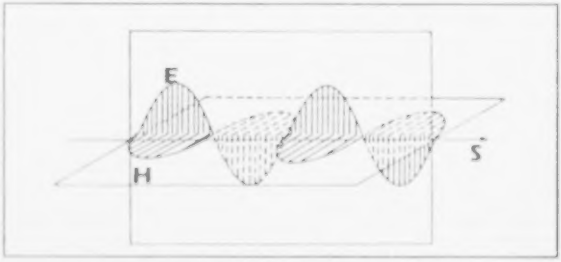
help and hurt

And finally, like other kinds of radiation, light can hurt as well as help. Anyone who has ever been sunburned can attest to one kind of hurt, and anyone who has ever eaten food can attest to a major kind of help.

Let's get more scientific now. Just what is this "light" we all know intuitively, but few know scientifically?

light as electromagnetic waves

Visible light, scientists tell us, is a form of energy. Energy in the form of electromagnetic waves. What is an electromagnetic wave? It is not easy to describe. Imagine a wave in a pond or in the

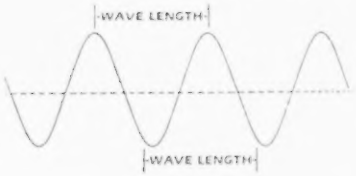


ocean. Notice how it changes, moves up and down, forward and back, in and out, in regular cycles. Now keep the movement, and take away the water! An electromagnetic wave is like that. A mysterious "field" of electromagnetic energy that moves in regular cycles.

how to measure

Electromagnetic waves are hard to describe in words, or picture in images, but they can be accu-

rately described in numbers. Two important measures are wavelength and frequency. How long the waves are and how frequently they move back and forth, up and down, out and in. In the case of light, these wavelengths are so small they are measured in micrometers–that is, millionths of a meter, about the diameter of a bacterium. Another way to visualize this small size–it would take between thirty-three thousand and sixty-six thousand visible light waves to make up an inch.



The frequency of visible light waves is as fast as the wavelengths are short. On the order of 10 to the tenth power cycles per second.

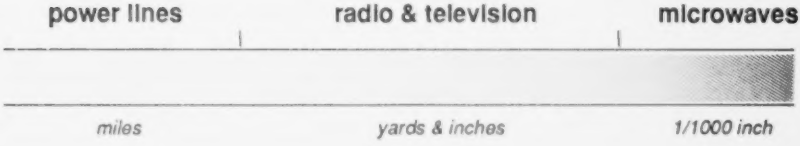
infrared waves

Visible light makes up the center of the electromagnetic spectrum charted below. Moving to the left, we come to waves with longer wavelengths. These are called infrared waves. They are invisible to the eye, but you can feel them as heat when they strike your skin.

We get infrared radiation from the sun to warm us here on earth. We also get infrared radiation from fires, from radiators in our homes, from light bulbs and from just about any other hot object. As a matter of fact, we also give out infrared radiation ourselves, generated by our own bodily heat.

microwaves

The next longer wavelengths are in the microwave region. These are useful to us today in



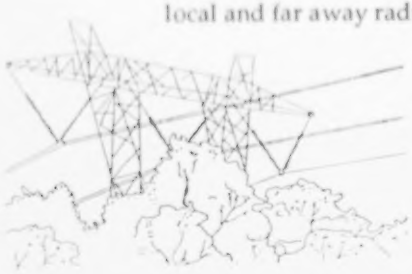
many ways. Microwaves are used to cook our food, to open garage doors, to communicate via CB radios, to guide airplanes and missiles and to trap speeders with radar.

radio, television and power lines

Move to still longer wavelengths (and lower frequencies) and we enter the band of broadcasting. Television, radio, short-wave radio, FM and AM radio, and finally the electromagnetic waves from electric power lines. These last and longest waves have lengths measured in thousands of miles and frequencies as low as sixty cycles per second.

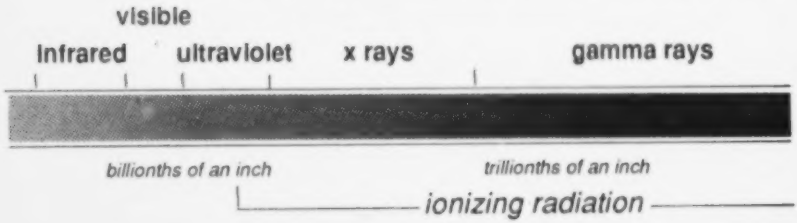
an eerie feeling

It can give you an eerie feeling to think of all the thousands of electromagnetic waves that hit and pass through your body every second of every day. This radiation comes from all directions and you are powerless to escape it. It comes from your local and far away radio and TV stations. It comes from your local power lines, telephone lines, international satellites orbiting the earth, and the personal computer next door. It comes from the ninety-three million mile away sun, the ten million light year away star, and the candle in your romantically lighted dining room.



not harmful

It may give you an eerie feeling to have so many electromagnetic waves invading your body but, so far as we know today, you don't have much to worry about healthwise. Looking directly at the



sun or any other intensely bright light can harm the retina of your eyes. Visible light, infrared light and microwaves can be intense enough to overheat and burn living tissue. But these effects are fairly easily avoided by common sense, fail-safe doors on microwave ovens, etc. (Some very recent studies do show possible harm from long exposure to high voltage power lines.) As we move in the opposite direction on our electromagnetic spectrum the dangers definitely do increase.

ultraviolet waves

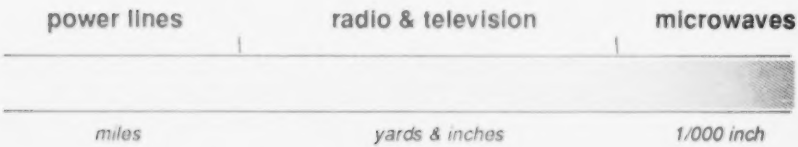
The electromagnetic waves with wavelengths just shorter and frequencies higher than visible light are called ultraviolet light. This is the kind of radiation that makes what are called *black light* displays. While your eyes cannot respond directly to ultraviolet waves, certain minerals can. They will glow, that is, change the ultraviolet radiation into visible light radiation that your eyes can see.

ozone shield

The sun sends out a strong dose of ultraviolet radiation to us here on earth every day. Fortunately there is a zone of ozone gas that surrounds the earth and filters out much of this potentially harmful ultraviolet light. But not all of it.

sunburn and skin cancer

The part that gets through the ozone is responsible for sunburn and for much of the skin cancer that plagues humans. Especially people who spend a lot of time in the bright sun, either from choice or from necessity.



Some scientists are worried today that this ozone shield is being destroyed by some modern industrial chemicals. If the ozone should decrease significantly, it would mean an increase–maybe a catastrophic increase–in human skin cancers. It could also result in other harmful effects on the living world.

ionizing radiation

As we keep moving in this direction toward still shorter wavelengths and higher frequencies, we run into still more powerful waves of radiation that scientists call *ionizing* radiation.

atoms and ions

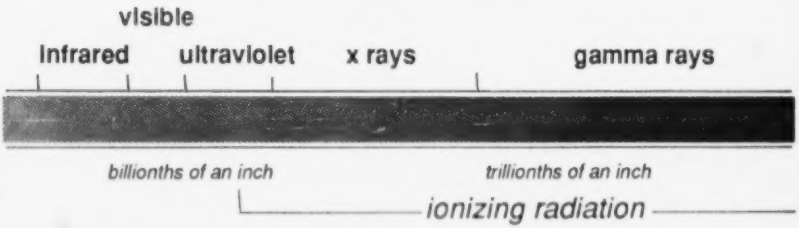
An ion is an atom that has lost or gained electrons. An ion, thus, has an electrical charge and is much more chemically reactive than a neutral atom. Ionizing radiation can penetrate deep into cells and knock electrons out of atoms in the cell. If cell atoms are ionized, unpredictable things can happen in the cell.

cell damage from ionization

If too many atoms are ionized, the cell's metabolism may get so out of whack that the cell dies. Or, worse, it may be that the ionized atoms are a part of the controlling DNA molecule in the cell's nucleus. Since it is the DNA that controls the cell's activities, especially in reproducing, this may result in uncontrolled cell reproduction. In other words, cancer.

x rays

The first band of ionizing electromagnetic waves beyond ultraviolet is the zone of x rays. X rays can penetrate skin and flesh to give a picture of bones, or show up cavities in the teeth.



medical and dental x rays

Over ninety percent of the total humanmade ionizing radiation that most people will ever receive in their lifetime will come from these medical and dental x rays. In most cases the benefits far outweigh the risks. However, there are some risks. Your own doctor or dentist is your best source for help in avoiding these risks.

Beyond x rays, physicists have discovered another range of ionizing radiation with even shorter wavelengths and higher frequencies. These are called gamma rays.

gamma rays

Gamma rays are emitted by radioactive elements on earth. We can control gamma rays in special industrial applications in order to see where no one had ever seen before–through thick metal plates for instance. This gives you a new way to check on the safety of bridges, of tankers and other heavy metal machines and structure.

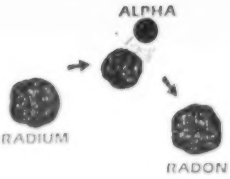
uses of gamma rays

At the opposite end of the materials spectrum, gamma rays are useful in medicine. They can be focused, for instance, to deliberately kill fast-multiplying cancer cells deep within the body–without harming normal cells.

radioactive atoms

Besides this spectrum of electromagnetic waves there is still another kind of energy radiation that is important today. This is the radiation that comes from radioactive elements–natural and humanmade. As well as from nuclear fission and fusion, natural and humanmade.

nuclear radiation



Most atoms on earth are stable, nonradioactive ones. However, a very small number of atoms are what we call radioactive. That is, the nuclei of these atoms are unstable. They spontaneously break apart. In that breaking apart they release radiation of four different kinds.

four kinds of nuclear radiation

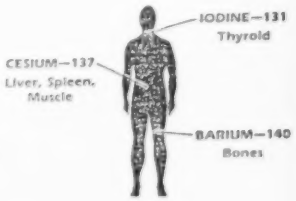
These four kinds of nuclear-generated radiation are alpha particles, beta particles, gamma rays and high-speed neutrons. Each of these four types of nuclear generated radiation has its own dangers and its own potential for good. Alpha particles are comparatively large in size and travel at high speeds.

alpha particles

An alpha particle is the same thing as a helium nucleus, two protons and two neutrons. It has a positive charge of two. Ordinarily alpha particles cannot penetrate the skin, but if radioactive atoms that produce alpha particles are taken in through the mouth or lungs, they can then disintegrate in the lungs, stomach, blood stream or other organs, and cause serious damage to body cells.

potential for cancer

Particularly dangerous are radioactive isotopes like iodine 131 which can accumulate in the thyroid gland. After many years of such exposure, cancer may result. Cesium 137 tends to accumulate in the liver, spleen and muscles. Barium 140 in the bones. Other radioactive atoms also have the potential to invade and harm the body from inside.



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beta radiation

Beta particles are much smaller. Beta particles are high speed electrons that shoot out of a radioactively disintegrating nucleus. Being smaller, they are also more penetrating.

β BETA PARTICLE

$\ominus$

= ELECTRON

gamma rays

Gamma rays also come from the radioactive decay of certain elements. Gamma rays, remember, are electromagnetic waves of very short wavelength and very high frequencies. And finally in the special case of nuclear fission or fusion–whether in bombs or power plants–high speed neutrons are emitted that can also cause ionizing destruction to atoms in cells. Like other kinds of radiation, they can also be useful in medical and industrial applications.

That completes our list of kinds of radiation known today. With one exception–cosmic rays.

cosmic rays

Cosmic rays are mysterious particles that come from unknown sources in outer space and bombard our earth continually. Our atmosphere shields us from these rays to some extent, as does earth's magnetic field. We can't do much to escape these cosmic rays. And we get more radiation from them if we ride in an airplane, live at a high altitude or spend much time at the North or South Poles. In all of these cases we get less atmospheric or magnetic field shielding.

best and worst?

If you had to rate the best and worst of all these forms of radiation from our human point of view, it would be impossible. Like most things in life,

forms of radiation have good sides and bad sides.

the rem

Scientists who specialize in the study of ionizing radiation have invented ways of measuring the bad side--the potential of radiation for harming living tissues. The most widely used measure for this is called a *rem* (short for Roentgen Equivalent in Man). Since a rem is a rather large unit measurements are usually expressed in *millirems*, that is, thousandths of a rem.

measures of hurt

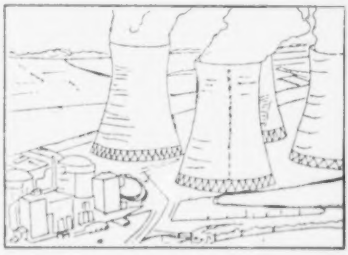
Rems and millirems are measures of the amount of ionizing radiation–no matter what the source--needed to produce a particular amount of damage in living tissue.

levels of radiation

At the lowest level, everyone on earth receives between thirty and one hundred and fifty millirems of radiation a year from natural sources like cosmic rays, naturally radioactive atoms in the air, soil, water, rocks, building materials and practically all food. Indeed we get about twenty millirems a year from our own bodies. And we radiate some of that to our family and friends.

radiation from nuclear power

Besides this natural radiation, everyone on earth gets very small amounts of radiation due to fallout from past nuclear bomb tests and from nuclear power plant accidents. At present, this is much less than the natural background rate described above. People living closest to the nuclear accident at Three Mile Island in Pennsylvania, for instance, received no more additional radiation than they would get from natural cosmic rays on one transcontinental flight across the United States–about two millirems.



Chernobyl

The famous Chernobyl nuclear accident in the Soviet Union resulted in significantly higher background radiation for a few days or weeks in many parts of Europe. Outside the Soviet Union these levels were still far below those considered safe by most radiation scientists.

most significant amount of radiation

By far the most significant ionizing radiation exposure most people get in their lifetime is from medical and dental x rays. One chest x ray, for instance, gives about seventeen millirems. A dental x ray gives about three hundred millirems. Neither of these is given to the whole body, however, which means a great deal less potential damage.

standards for safety

A total of five rems of whole body radiation a year is the government safety maximum for radiation industry workers. For the general public the standard is lowered to one half a rem (five hundred millirems) a year.

fatal doses

As exposures go higher than this, there is more significant risk, but at present it is very difficult to estimate accurately. We know that over one thousand rems at one time is almost always fatal. However, one thousand rems over a period of years would not be fatal. It might not even be harmful! We know that over one hundred rems a year to the whole today is dangerous, however, and does increase the long term risk of cancer.

accentuate the positive

But we should not close, as we did not open, with the negative. With all the emphasis on risks in radiation, we may be in danger of forgetting the other sides, the positive sides.

windows of opportunity

Not only are x rays, gamma rays, alpha rays, beta rays, neutrons and even cosmic rays potentially dangerous, you could also call all of them *windows of opportunity*.

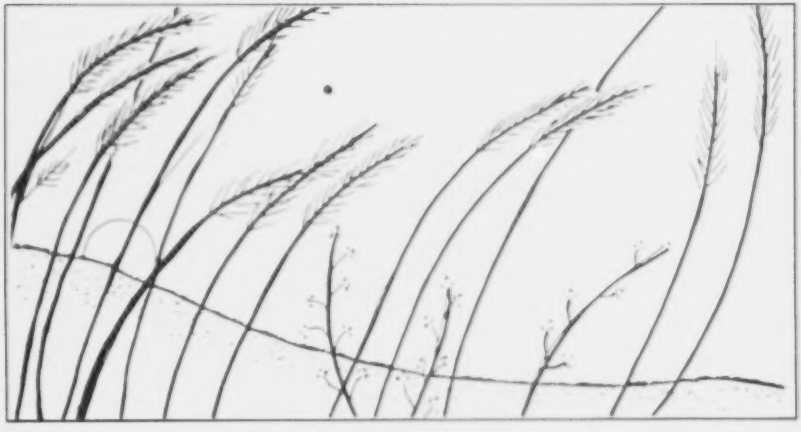
Where would the living world be, for instance, if green plants had not opened up a few billion years ago to the opportunity visible light radiation presented to the world? The opportunity to invent photosynthesis and make food and energy available for themselves first, and for animals later.

And what about animals? Where would we be if eyes had not been invented to take advantage of the opportunity visible light radiation offered to see and to explore our world?

So, too, we have only begun to explore the opportunities that new kinds of ionizing radiation present to our world. Opportunities to understand our place in this radiant universe–and to make a better place of our spaceship earth home.

the sunny side of the street

And if you are ever tempted to forget these elementary facts, take a walk today–on the sunny side of the street.



TIME ...

To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.

EVENTS IN WORLD HISTORY		EVENTS IN SCIENCE & TECHNOLOGY
	1600	1600
1616 death of Shakespeare		
		1665 Newton discovers color spectrum
	1700	1700
1776 American Revolution		
	1800	1800
		1803 Young proves light comes in waves
1861-65 Civil War		mid-19th century Faraday, Maxwell and others discover electromagnetic spectrum
	1900	1890-1910 1900 Becquerel, Curie and others discover radioactivity, x rays and other forms of radiation
1914-18 World War I		
1939-45 World War II		1935-present new discoveries and technology in fission and fusion

SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you locate the important events and people discussed in this book.

1. Ionian Greece — Where the world's first scientist/philosophers lived and worked. Now a part of Turkey.

2. Bavaria, Germany — Here at the University of Wurzburg Henri Becquerel first discovered x rays. Many other universities in Germany were leaders in nineteenth and twentieth century science.

3. Scotland — Home country of James Clerk Maxwell who put together the first complete theory of electromagnetic radiation in mid-nineteenth century.

4. London, England — Site of the famous Young lecture to the Royal Society in 1803 which first proved that light came in waves.

5. Paris, France — Becquerel, Curie and others worked here to unravel mysteries of radiation near the turn of the century.

SPIRIT ...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things–connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit worked in the past–and are working today.

alpha radiation — High-energy radiation that comes from radioactive atoms when they break apart. Alpha particles are identical to helium nuclei. (p. 8-9, 19)

beta radiation — High-speed electrons that come from radioactive atoms when they break apart. (p. 9, 20)

black light — Popular name for the light that comes from minerals that glow when exposed to ultraviolet radiation. (p. 4, 16)

cosmic rays — Radiation that comes to earth from outer space. (p. 20)

electromagnetic spectrum — Electromagnetic waves arranged in order of wavelengths (or frequencies). (p. 4-7, 13-18)

fission — When certain heavy nuclei break into two or more parts releasing large amounts of energy. (p. 10, 20-21)

fusion — When certain light nuclei combine to make larger nuclei releasing large amounts of energy. (p. 10-11)

gamma rays — Electromagnetic waves of very short wave length and very high frequency. (p. 8, 19-20)

infrared — Radiation band with wavelengths just longer than visible light. Useful in heating. (p. 5, 14)

ion — An atom that has lost or gained electrons, and thus has a positive or negative charge. (p. 17)

ionizing radiation Radiation that can ionize atoms and is especially dangerous to living tissues. Comes from radioactive decay, from fission and fusion, and from short wavelength, high frequency electromagnetic waves. (p. 17-19)

isotopes Varieties of the same atom with different numbers of neutrons in their nuclei. (p. 10, 19)

microwave Radiation band with wavelengths longer than infrared and shorter than radio waves. Used in cooking, in radar and CB radios. (p. 6, 14)

neutron A subatomic particle with no charge that, along with protons, makes up the nucleus of all atoms. In the case of fission or fusion, high-speed neutron radiation is emitted. (p. 9-10, 21)

nucleus The very small center of atoms. Composed of protons and neutrons. (p. 9-11, 19-20)

ozone A form of the element oxygen that has three atoms to the molecule instead of the usual two. On the surface of the earth, dangerous to human health. In the upper atmosphere, forms a useful shield to keep out excessive ultraviolet radiation from the sun. (p. 16-17)

radiation See this booklet.

radioactive A property of a very small proportion of atoms on earth whereby they spontaneously disintegrate, releasing radiation that can be useful or harmful. (p. 8-11, 18-20)

radium One of the first radioactive elements to be discovered. (p. 8)

rem Short for Roentgen Equivalent in Man. A measure for how dangerous radiation is to living tissue. (p. 21-22)

speed of light 186,000 miles per second. All electromagnetic radiation travels at this same speed. (p. 12)

ultraviolet Radiation with wavelengths just shorter than visible light. Dangerous in producing sunburn and skin cancer. (p. 4, 16-17)

uranium Naturally radioactive element. One of its rarer isotopes–U-235–is capable of fission and is used in nuclear bombs and nuclear power plants to produce large amounts of energy. (p. 9-10)

wavelength The distance from one point on any wave to the corresponding point on the next wave (p. 14).

x rays Radiation with wavelengths shorter than ultraviolet and longer than gamma rays. Useful in medical and industrial applications, but dangerous to living tissues. (p. 7, 17-18, 22)

In addition to the above, *RADIATION* also teaches about other important people, places, things and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following (for help, check the pages listed in this Learning Power Book, as well as your dictionary and encyclopedia):

AM radio (p. 15); **atom** (p. 9-10, 12); **barium 140** (p. 19); **Becquerel, Henri** (p. 7); **cancer** (p. 7, 17); **cesium 137** (p.19); **Chernobyl** (p. 22); **Curie, Marie** (p. 8); **DNA** (p. 17); **Faraday, Michael** (p. 5); **FM radio** (p. 15); **frequency** (p. 6, 13-14); **generator** (p. 5); **helium** (p. 9, 19); **hydrogen** (p. 10-11); **iodine 131** (p. 19); **Maxwell, James Clerk** (p. 5-6); **motor** (p. 5); **Newton, Isaac** (p. 2-3); **physicist** (p, 5, 9); **proton** (p. 19); **radar** (p. 15); **Roentgen, Wilhelm** (p. 7, 21); **vacuum tube** (p. 7); **Three Mile Island** (p. 21); **Young, Thomas** (p. 3-4).

STUDY SUGGESTIONS ...

1. Ozone is an interesting chemical. It is harmful when we breathe too much of it. It is necessary at high altitudes to keep out potentially harmful radiation coming to us from the sun. In other words, we don't want ozone and we do want ozone. Investigate the details of this problem today. You may want to focus on new proposals to limit pollution in areas like Los Angeles, to ban air-conditioning chemicals, etc. Look, also, into the contribution trees make to ozone accumulation.

2. Recently there has been a good deal of public concern about radon exposure. Radon is a rare and inert–but radioactive–gas that is released naturally from some soil and rock formations. It tends to accumulate in houses and other buildings, especially when they have too little air circulation. Investigate the current status of this danger in your own community. Organize tests for radon in your own home and school. See your nearest hardware store for inexpensive kits to make these tests.

3. Knowing more about the lives of scientists can make science all the more interesting. See the bibliography for suggestions to read about famous and not so famous scientists of the past and present. Also watch for stories in your daily newspaper about current scientists.

4. Investigate specific ways the sun's radiation can help and harm. One unusual application of sunlight today is in combating depression. See if you can come up with others.

5. The most controversial area of radiation study today is nuclear radiation. Most people have an opinion, pro or con, about nuclear power. Whatever your opinion is now, make a deliberate attempt to read and listen to people with an opposite point of view.

6. Geologists and archaeologists use radioactive dating of rocks and organic materials as basic data in their science. Investigate these methods, such as potassium-argon, fission-track and radiocarbon dating. How reliable are they? Another interesting study would be to investigate the use of radioactive tracing in ecology or in genetics or both.

7. One of the greatest challenges scientists face today is communicating their insights to nonscientists. This is particularly difficult when it comes to radiation and to an assessment of the risks here. The problems are not all scientific. They involve people's values and perceptions. See

the new book by Aaran Wildavksy in the bibliography for provocative information and points of view on this subject.

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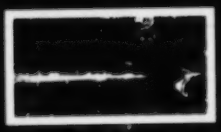

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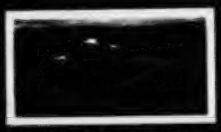

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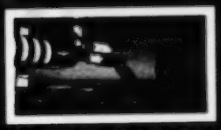

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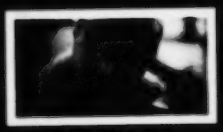

The Gene

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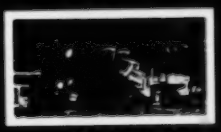

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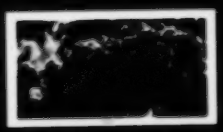

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